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Feeding Behavior, Food Consumption, Growth, and Survival of Hybrid Grass Carp (Hypophthalmichthys nobilis x Ctenopharyngodon idella) In South Dakota

Marc C. Harberg

FEEDING BEHAVIOR, FOOD CONSUMPTION, GROWTH, AND SURVIVAL OF HYBRID GRASS CARP (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) IN SOUTH DAKOTA

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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FEEDING BEHAVIOR, FOOD CONSUMPTION, GROWTH, AND SURVIVAL OF HYBRID GRASS CARP (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) IN SOUTH DAKOTA

Abstract

Mark C. Harberg

Plant preference of yearling hybrids (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) was examined under control conditions at the Gavins Point National Fish Hatchery, Yankton, South Dakota and under field conditions in two stockwater impoundments in south-central South Dakota. In feeding trials, conducted in a 0.07 ha hatchery pond, hybrid grass carp selected *Najas guadalupensis*, *Chara* sp. and *Potamogeton pectinatus*. *Ceratophyllum demersum* and *Myriophyllum spicatum* were not consumed. Under field conditions N. *guadalupensis* also appeared to be preferred while C. *demersum* was not.

Feeding behavior, daily consumption, growth and survival were also evaluated in the two stockwater impoundments. Hybrids averaging 51 g were stocked in the ponds at rates of 17 and 31 kg/ha. No discernible control of aquatic vegetation was attained by the hybrids at these stocking rates.

Feeding activity of the hybrids was diurnal and took place primarily in shallow water. The hybrids fed most heavily from 0400 to 0800 and from 1600 to 2000. Total daily consumption was 44.0% of body weight at 23 C and 30.4% at 15 C.

Survival of the hybrids from 24 April 1982 to 18-19 September 1982 was 59.1 and 32.2% in Ponds 1 and 2 respectively. Hybrids surviving to the end of this period averaged 542 g in Pond 1 and 591 g in Pond 2, representing 3.3 and 3.6 g/day growth rates.

INTRODUCTION

Aquatic macrophytes are major producers of organic matter in aquatic ecosystems and provide necessary food and shelter for fishes. In addition, vascular aquatic plants serve as an essential food source for aquatic insects and waterfowl (Welch 1952). However, excessive macrophytic growth accelerates eutrophication, inhibits development of planktonic and benthic organisms, and allows surplus recruitment of some juvenile fishes. Large amounts of aquatic macrophytes also inhibit recreational activities, reduce flows and storage capacities in irrigation systems, and hamper fish culture operations (Vietmeyer 1976). In order to curb these negative impacts, efficient, inexpensive, and environmentally safe methods of aquatic vegetation control are needed by resource managers.

In 1963 the white amur, *Ctenopharyngodon idella,* was introduced to the United States for use in aquatic vegetation control (Pflieger 1978). Subsequent studies have reported that the white amur is an effective agent in reducing aquatic plant growth (e.g. Avault 1965; Edwards and Moore 1975; Terrell and Terrell 1975; Mitzner 1978). However, concern for potential natural reproduction of the white amur has prevented this species from gaining universal acceptance (Vietmeyer 1976). This concern has heightened following the report by Conner et al. (1980) that larval white amur have been collected in the lower Mississippi River. Natural reproduction and widespread distribution of white amur, resulting in overgrazing of the aquatic plant community, could have adverse effects on both fisheries and waterfowl resources (Stanley et al.

1978).

The hyrid grass carp, an intergeneric cross between the female white amur and male bighead carp, Hypophthalmichthys nobilis, represents a potential alternative. Throughout the remainder of this paper the cross between these two fish will be referred to as the hybrid. Beck et al. (1980) reported that hybrids possessing a triploid chromosome number are probably unable to produce viable gametes. The hybrid was first produced in the United States in 1979 by J.M. Malone & Son Enterprises and the Arkansas Game and Fish Commission. However, triploid fish were not produced in commercial quantities until 1981. Consequently, little published information exists on the triploid which grow faster and consume more vegetation than the diploid fish produced in 1979 and 1980 (Cassani and Caton 1983; Malone pers. comm. [1]). Morphologically and superficially the hybrid is similar to the white amur. Comparable features include the pharyngeal teeth structure, length of the digestive tract, size of the head, and the eye and mouth position (Hestand and Chapman 1980; Kilambi and Zdinak 1981; Sutton et al. 1981). Shireman et al. (in press—b) reported that white amur had greater growth and daily food consumption rates than the hybrid under laboratory conditions. Kilambi and Zdinak (1980), however, found that daily food consumption and growth in the laboratory were not significantly different between the hybrid and the white amur.

The goal of this study was to determine if the hybrid is a feasible means of vegetation control in South Dakota. To achieve this

[1] J.M. Malone and Sons Enterprises Memorandum. February 24, 1982.

goal three factors were investigated: (1) food preference of the hybrid under laboratory and field conditions, (2) food consumption of the hybrid, and (3) growth and survival of the hybrid under field conditions.

STUDY AREA

This study was conducted at two locations. During 1981, hybrids were evaluated under controlled conditions at the Gavins Point National Fish Hatchery near Yankton, South Dakota. The hybrids were held in a 0.07 ha hatchery pond with a maximum depth of 2.4 m.

In 1982 hybrids were stocked in two stockwater impoundments in north-central Tripp County, South Dakota (43° 39' N, 99° 54' W) (Fig. 1). The stockwater ponds were situated in a series of rough, broken ridges which parallel the White River. This area is characterized by moderately deep clay soil of medium fertility underlain by Pierre Shale (Springer 1979). Native mid grasses cover the surrounding watersheds and cattle ranching is the predominant enterprise. Pond 1 was constructed with an earthen spillway at an elevated level to maximize storage capacity. Consequently depth and surface area fluctuated with precipitation. During this study the surface area was 0.53 hectares, maximum depth was 3.0 m, and mean depth was 1.4 m. Pond 2 was fed by a permanent spring in addition to runoff and therefore a pipe was installed to minimize operation of the earthen spillway. Accordingly, a constant water level was maintained. It had a surface area of 0.52 hectares, maximum depth of 1.5 m, and mean depth of 1.0 m. Both ponds had a history of excessive quantities of aquatic vegetation. The golden shiner, *Notemigonus crysoleucas,* was the only fish species present in the ponds prior to hybrid stockings.

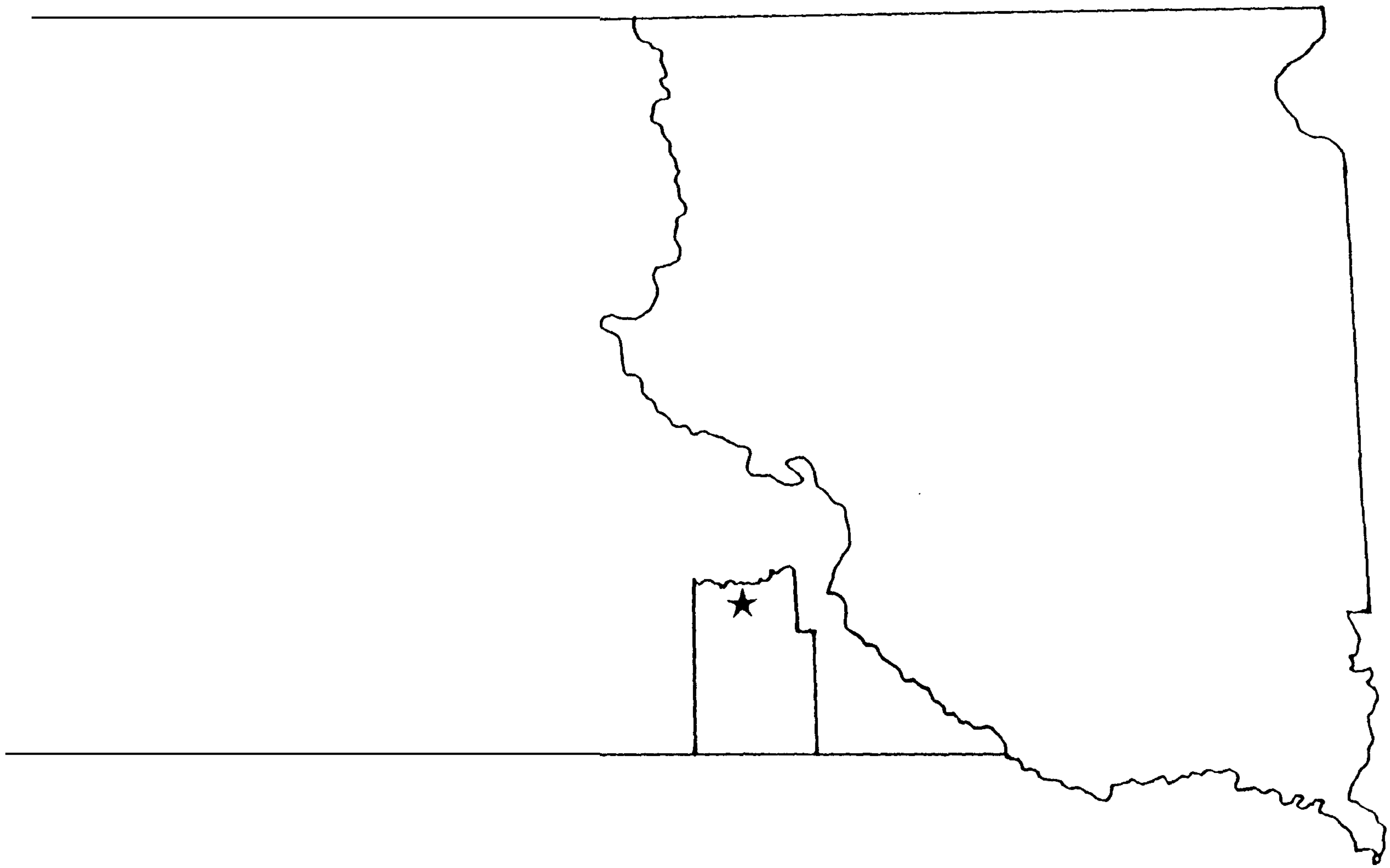

Figure 1. Location of stockwater ponds stocked with hybrids (*Ilypophthalmichthys nobilis* x *Ctenopharyngodon idella*) in Tripp County, South Dakota.

METHODS

Plant Preference

Plant preference studies were conducted under both controlled conditions (1981) and field conditions (1982). All hybrids used in these experiments were produced at J.M. Malone & Sons Enterprises, Lonoke, Arkansas.

Two consecutive feeding trials were conducted from 31 July to 11 August 1981. Five yearling hybrids (1980 yearclass), averaging 236 g, were placed in each of three pens made of 19 mm bar mesh plastic netting. The pens, measuring 1.1 x 1.1 x 1.2 m, were located near the center of the 0.07 ha hatchery pond. A preweighed sample of _Chara_ sp., _Najas guadalupensis_, _Potamogeton pectinatus_, _Myriophyllum spicatum_, and _Ceratophyllum demersum_ were placed in each pen for a five day period. Wet weight of each plant species was approximately 50-75% of the average individual fish weight. A control sample, also consisting of a preweighed sample of each species, was suspended within the pond. After each trial, plant samples were removed, blotted, weighed to the nearest 0.1 g, and the biomass adjusted for changes underwent by the corresponding control sample. The percentage of each plant species consumed was calculated and analysis of variance was used to test for differences. Waller-Duncan's K-ratio t test was employed to categorize the plant species into similar groupings based on percentage consumed.

In 1982 an investigation of plant preference under field conditions was carried out in two Tripp County stockwater ponds.

Yearling hybrids (1981 yearclass), averaging 51 g and 150 mm, were stocked in the ponds on 24 April 1982. Pond 1 and Pond 2 were stocked with 176 and 326 fish at rates of 17 and 31 kg/ha, respectively. Plant preference was evaluated by comparing the biomass of each plant species present within control areas to that present in areas subject to hybrid feeding. Each stockwater pond was divided into three sections, topographically surveyed, and 0.9 m depth contours delineated. Exclosures, measuring 2 x 2 m, were constructed of vexar plastic utility netting and randomly located in the 0-0.9 m and 0.9-1.8 m depth intervals of each section. Permanent buoys were also randomly placed in these depth intervals of each section to identify exposed sampling sites (Figs. 2 and 3). Each exclosure was divided into four areas and each month a vegetation sample was removed from the area previously assigned to that month at random. Samples from the exposed area were collected 1.0 m from each buoy in a predetermined direction chosen at random.

Vegetation samples were collected from each exclosed and exposed sampling site on 15-16 June, 15-16 July, 16-17 August, and 10-12 September, 1982. All vegetation samples were collected with a steel, tubular sampling device modeled after a sampler described by Caldwell (1980). The device sampled a 0.25 m^2 area and was lowered onto the substrate using a winch and crane apparatus erected in a 5 m flat bottom boat. The vegetation was removed with a modified silage fork with 6.4 mm hardware cloth attached to the prongs. All samples were separated by species, allowed to drip dry over a screen table, and weighed to the nearest 0.1 g. Analysis of variance was used to detect differences in species biomass between the exclosed and exposed areas.

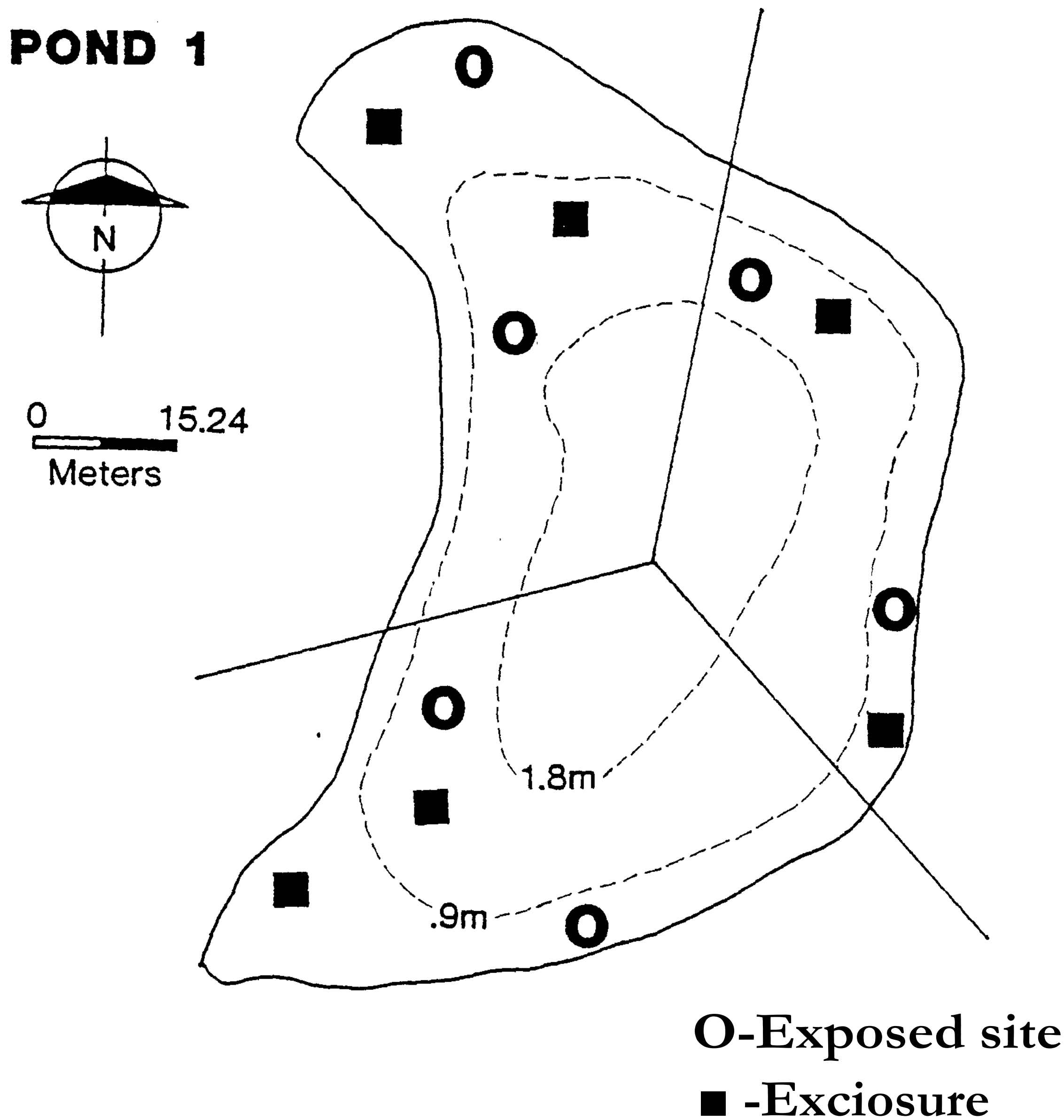

Figure 2. Location and arrangement of vegetation sampling stations used to evaluate plant preference of hybrids (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) stocked in Pond 1 during the summer of 1982.

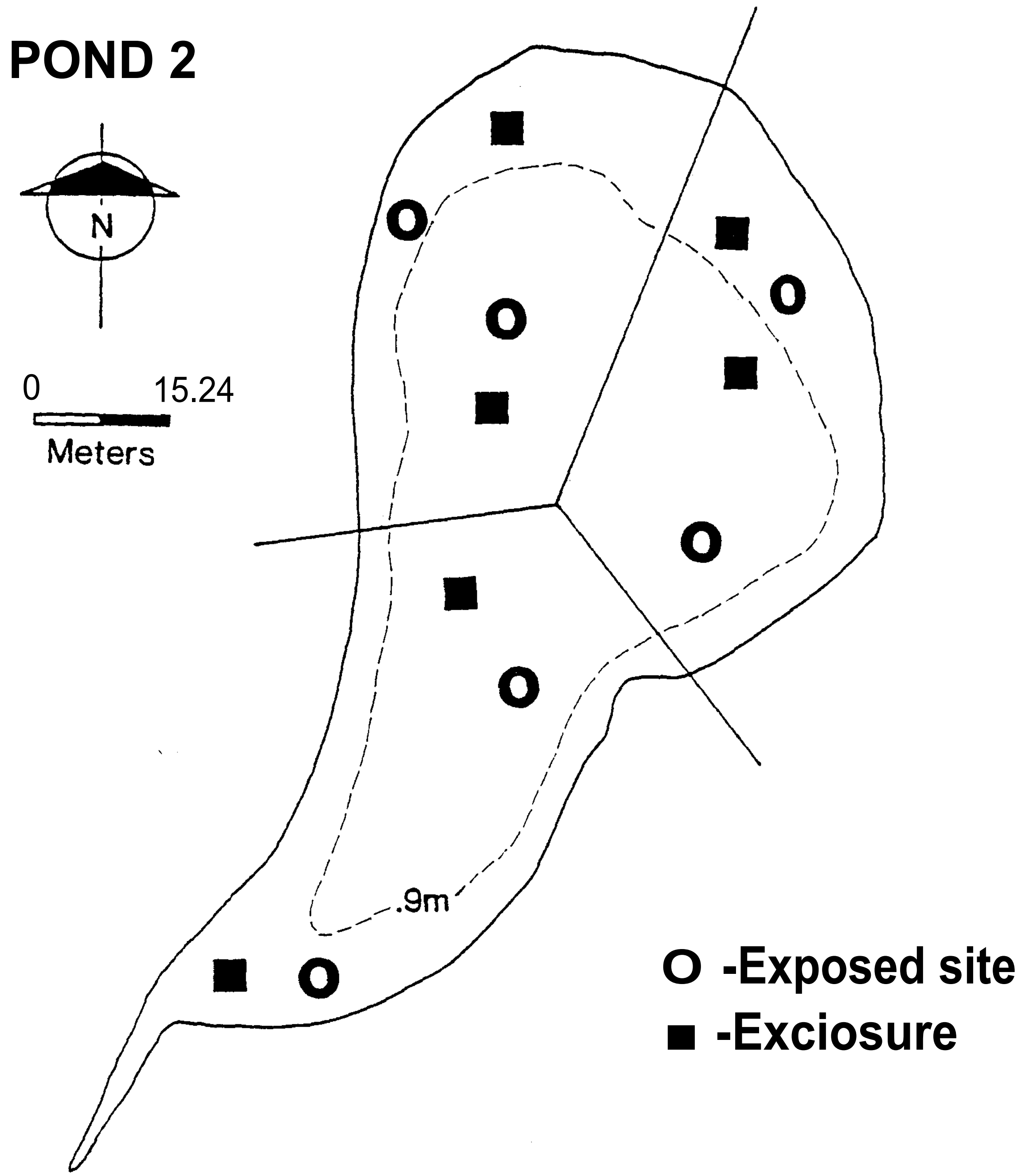

Figure 3. Location and arrangement of vegetation sampling stations used to evaluate plant preference of hybrids (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) stocked in Pond 2 during the summer of 1982.

Plant Consumption

Daily consumption rates of vearlinn hvhr;Ao (704,
(1968) reported that below 14 C food consumption of grass carp decreased to near maintenance ration. Daily consumption rates were determined using the following equation developed by Elliot and Persson (1978):

$$Ci = \frac{(Si - S_o e^{-Rt})Rt}{1 - e^{-xt}}$$

where:

Ci = biomass consumed during the ith interval (% body weight)

Si = biomass of food in the foregut at the end of the ith interval (% body weight)

S_o = biomass of food in the foregut at the beginning of the ith interval (% body weight)

R = exponential rate of foregut evacuation

t = length of interval (hours)

This equation assumes a constant rate of food consumption during the interval considered. Daily consumption rate was calculated by summing the values obtained for six consecutive four hour intervals.

The daily feeding pattern of the hybrid was determined in Pond 2 on 18-19 September 1982. Three fish were collected at four hour intervals throughout a 24 hour period with 240-volt alternating current electrofishing gear. The digestive tract was severed at the first loop of the intestine and the esophagus (approximately 15.8% of the digestive tract) and the contents of this section (henceforth referred to as the foregut) were removed and wet weights measured. Hickling (1966) found that the water content of aquatic vegetation changes little in the digestive tract of the grass carp. Only the foregut was used so that reduction in food biomass due to digestion was minimized. Most digestive enzymes occur in the middle portion of the grass carp digestive tract (Hickling 1966).

Food evacuation rate of fish has been reported by a number of investigators to increase with increasing temperature (Brett and Higgs 1970; Tyler 1970; Edwards 1971; Elliot 1972). However, evacuation rate is not affected by size of fish, size of meal, short starvation periods or size of food (Kitchell and Windell 1968; Tyler 1970; Elliot 1972). This allowed evacuation rates to be determined at 15 C and 23 C using hybrids averaging 546 g and 89 g, respectively. The following procedure was used at both temperatures: 1) twenty-four hybrids were collected from heavily vegetated ponds at approximately 0800 hours 2) the hybrids were transferred to food free holding tanks which were maintained at constant temperature 3) at 45 minute intervals three fish were sacrificed and the contents of the foregut removed and weighed until the foregut was empty. The relationship between time (X) and mean biomass of food in the foregut (Y) follows a negative exponential function (Brett and Higgs 1970; Edwards 1971; Elliot 1972; Grove and Crawford 1980). This exponential relationship can be described by the following equation:

$$\log Y = \log A - RX$$

where, A is the y-intercept and R is the regression coefficient and the exponential rate of evacuation. Regression equations were calculated for the data at both temperatures. These models were tested for significance using analysis of variance.

Following an application of 1.0 mg/liter rotenone on 18-19 September 1982 the hybrids were collected so that growth (g/day) and survival rates could be calculated. The daily consumption rate (% body weight), estimated previously at 23 C, was applied to the average biomass of hybrids present during a vegetation sampling interval to obtain an estimate of total daily consumption. It was assumed that all mortality took place soon after stocking. Total daily consumption was multiplied by the number of days between sampling dates to estimate the potential consumption of the hybrids for each sampling interval.

Water Quality

Water quality analysis was performed in August and November 1981 and February, April, and August 1982. Analysis was conducted at the surface, bottom, and mid-depth at the deepest point of both ponds. Conductivity, salinity, and temperature were measured with a YSI model 33 S-C-T meter. Alkalinity, dissolved oxygen, hardness, pH, and turbidity were measured with a Hach water chemistry kit. Nitrate (N) and phosphate (ortho) were measured, by standard methods, at the Water Quality Lab, South Dakota State University, Brookings, South Dakota.

RESULTS

Plant Preference

Both controlled feeding trials in 1981 resulted in significant (P<.0001) differences in plant consumption by the hybrids (Appendix Table 1). In each trial hybrids nearly eliminated _Najas guadalupensis_ and _Chara_ sp. (Figure 4). _Potamogeton pectinatus_ was almost completely consumed in trial 2 but was utilized to a lesser degree in trial 1. _Myriophyllum spicatum_ and _Ceratophyllum demersum_ were not consumed in either trial. When the results of the feeding trials were combined, Waller-Duncan's K-ratio t-test categorized the five plant species into three groups (Table 1). These groups represented those species most preferred, that species moderately preferred, and those species least preferred.

Seven species of aquatic vascular plants and one species of alga were collected from the two stockwater ponds (Appendix Table 2). _Potamogeton foliosus_ and _Potamogeton pusillus_ were designated _Potamogeton_ spp. due to morphological similarities. All species occurred in both ponds with the exception of N. _guadalupensis_ which was found only in Pond 1. Filamentous algae were also present in the ponds but was not evaluated. By July, Pond 1 was dominated by N. _guadalupensis_ and _Potamogeton_ spp. which accounted for 35 and 34% of the total vegetation biomass, respectively (Table 2). _Chara_ sp. (49%) and _Ceratophyllum demersum_ (26%) accounted for the majority of plants present in Pond 2. In September both ponds were dominated by C. _demersum_ which made up 58 and 80% of the total biomass of

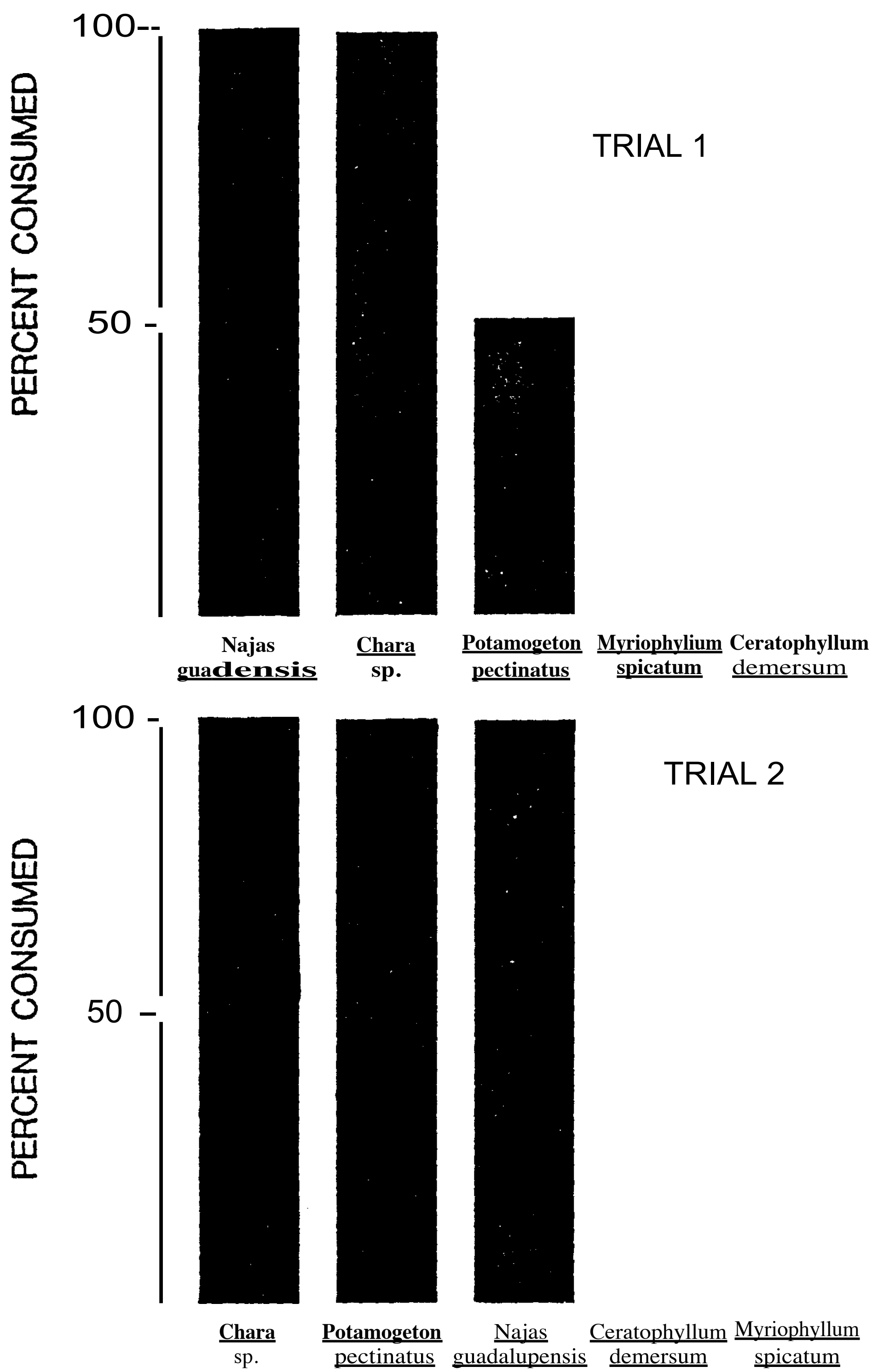

Figure 4. Percent plant consumption by hybrids (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) in feeding trials conducted at Gavins Point National Fish Hatchery, Yankton, South Dakota, 1981.

Table 1. Waller-Duncan's K-ratio t-test results of percent plant consumption by hybrids (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) under controlled conditions.

Plant Consumption Rates				
Ceratophyllum demersum	*Myriophyllum spicatum*	*Potamogeton pectinatus*	*Chara* sp.	*Najas guadalupensis*
0.0	0.0	74.7	99.0	99.0

*Horizontal lines indicate similar preference by hybrids.

Table 2. Biomass (kg/ha) of vegetation present in the stockwater ponds each month based on exclosed samples.

Vegetation	June	July	August	September
Pond 1				
Najas guadalupensis	0.0	4,387.9	7,040.7	1,140.0
Chara sp.	0.0	2,022.6	797.9	789.2
Potamogeton pectinatus	350.0	512.1	211.3	0.0
Potamogeton spp.	163.4	4,323.4	694.7	4.7
Potamogeton nodosus	0.0	528.7	1,640.0	2,069.2
Ranunculus longirostris	0.0	78.7	40.8	0.0
Ceratophyllum demersum	1,008.7	801.3	1,327.4	5,587.4
TOTAL	1,522.1	12,654.7	11,752.8	9,590.5
Pond 2				
Najas guadalupensis	0.0	0.0	0.0	0.0
Chara sp.	7,196.0	5,538.7	184.6	0.0
Potamogeton pectinatus	108.1	372.7	326.7	1,443.3
Potamogeton spp.	311.9	1,151.3	86.0	1.9
Potamogeton nodosus	0.0	0.0	0.0	26.7
Ranunculus longirostris	779.4	1,378.1	1,390.6	346.0
Ceratophyllum demersum	4,476.0	2,905.4	6,781.9	7,050.6
TOTAL	12,871.4	11,346.2	8,769.8	8,868.5

vegetation present in Ponds 1 and 2, respectively.

No significant (P<.05) reduction in total biomass of vegetation or of any individual species was detected in either pond throughout the study period. Although not significant, all species except *Ceratophyllum demersum* exhibited a decrease in biomass in the exposed area of the 0—0.9 m depth interval (Figure 5). In the 0.9—1.8 m interval N. *guadalupensis* was the only species which underwent a reduction in biomass. All other species became more abundant in the exposed area of this deeper interval. A significant (1^{3}(.05) interaction between depth and the effectiveness of the hybrids was present for *Potamogeton pectinatus* (Appendix Table 3). This indicated that the effect of the hybrids on the biomass of P. *pectinatus* was depth dependent. No significant (P<.05) interaction occurred with the other plant species.

Plant Consumption

Green material present in the digestive tracts of hybrids used in these experiments was in a continuous bolus indicating feeding had been uninterrupted prior to capture (Hickling 1966). Complete foregut evacuation occurred between 4.50 and 5.25 hours at 15 C and between 3.00 and 3.75 hours at 23 C (Table 3). The linear models relating time to the natural logarithm of food biomass present in the foregut are shown in Figure 6. These linear relationships were significant (P<.05) (Appendix Table 4) and had correlation coefficients of .75 and .77 at 15 and 23 C, respectively. The exponential rate of foregut evacuation was -1.6 at 15 C and -2.3 at 23 C.

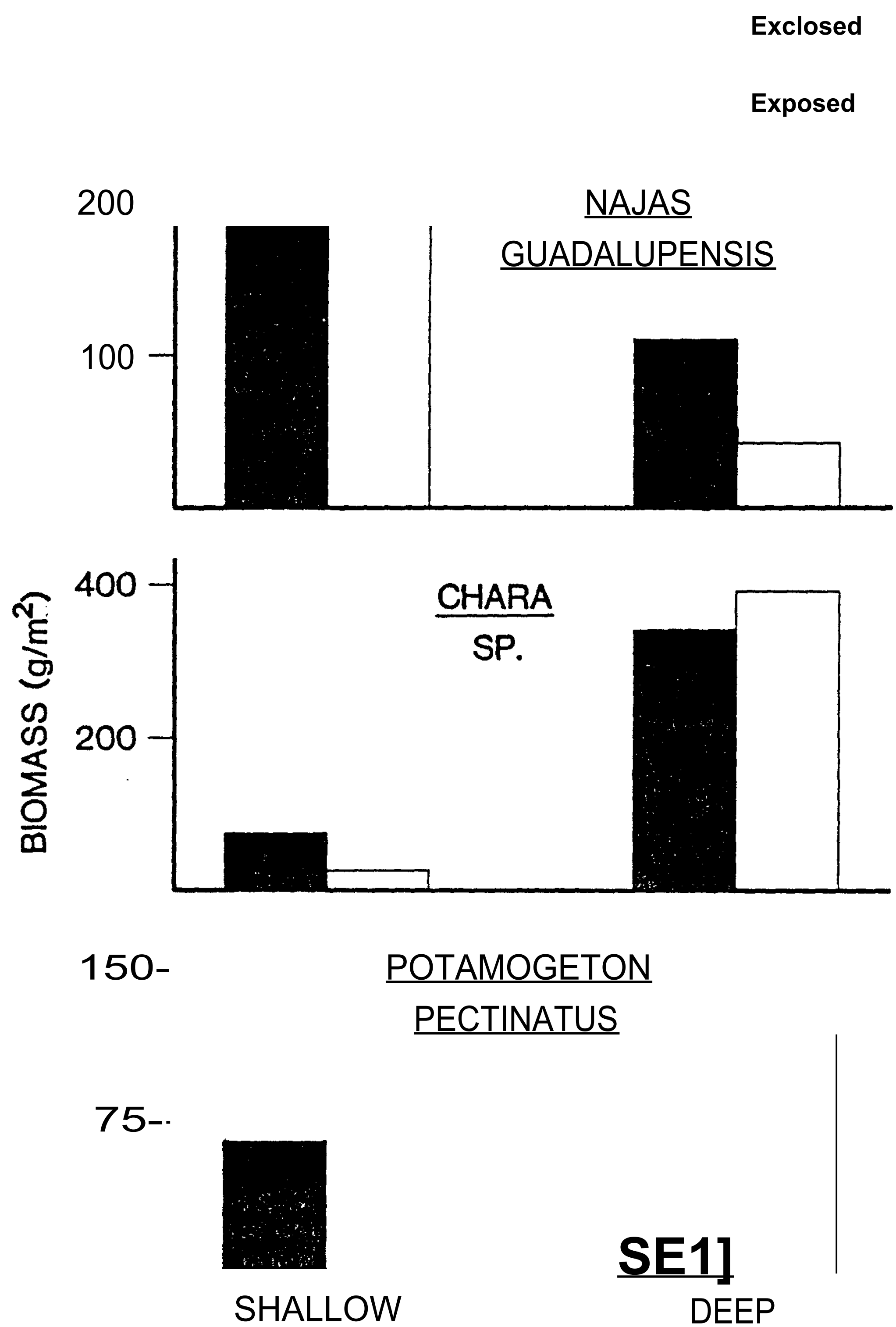

Figure 5. Mean biomass of vegetation present in the exposed and exciosed areas of the stockwater ponds throughout the study period.

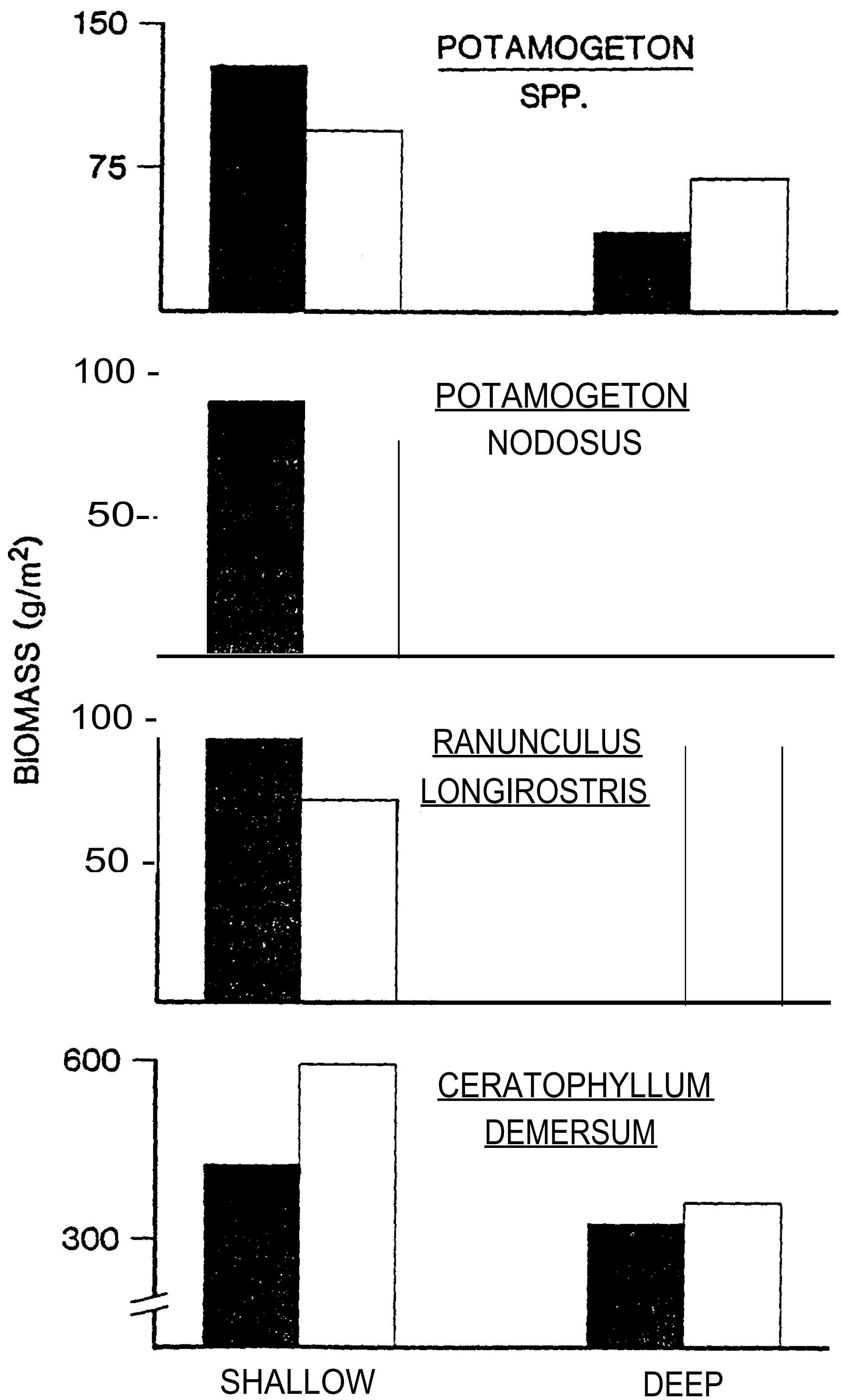

Figure 5. continued.

Table 3. Mean biomass of food in the foregut at 0.75 hour intervals after feeding of hybrids (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) held in food free holding tanks at 23 C and 15 C.

Time (hours)	Biomass (% body weight)	
	23 C	15 C
0.75	0.30	0.60
1.50	0.28	0.54
2.25	0.28	0.32
3.00	0.14	0.12
3.75	0.00	0.25
4.50	-	0.14
5.25	-	0.00

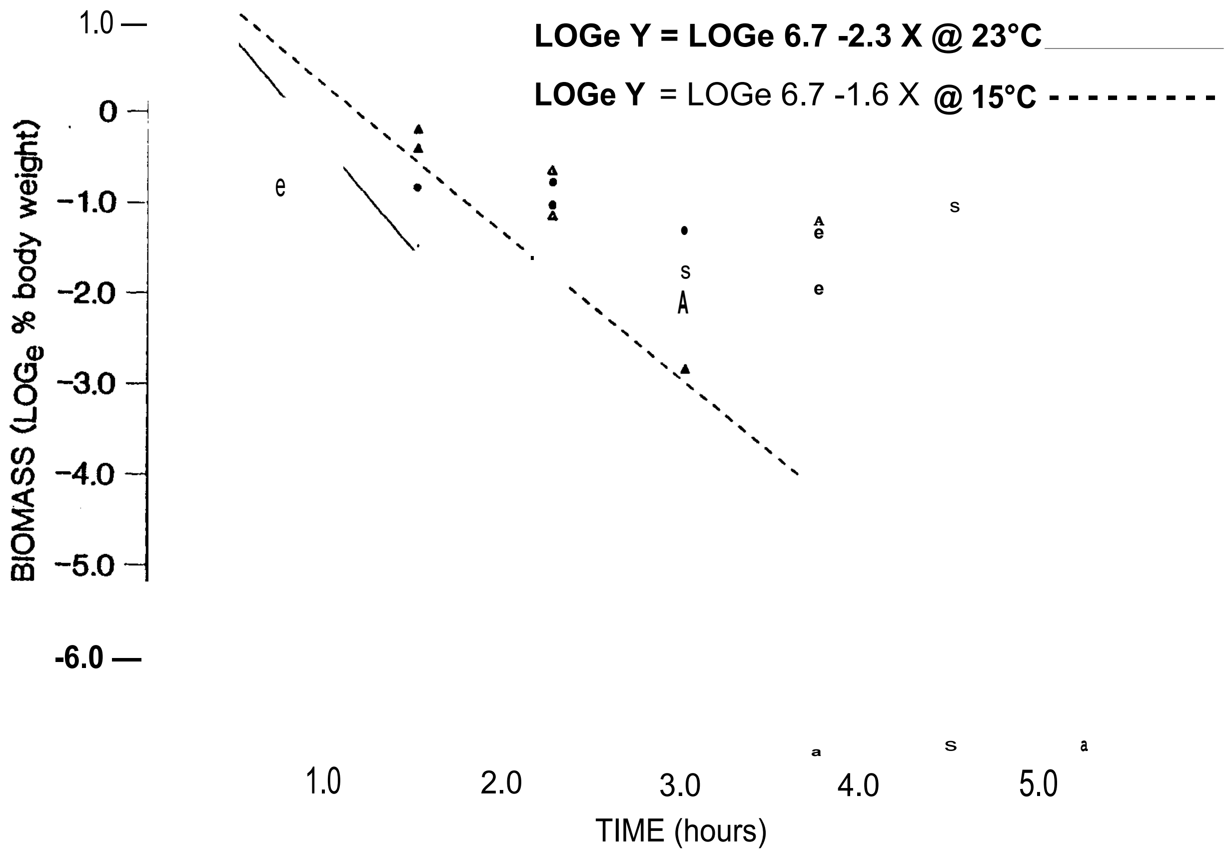

Figure 6. Linear models relating time to the natural logarithm of food biomass present in the foregut of hybrids (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) held in food free holding tanks.

The daily feeding pattern of hybrids in Pond 2 was characterized by two activity peaks (Figure 7). The first peak occurred at 0800 when a mean food biomass of 1.8% of body weight was present in the foregut. The second activity peak occurred at 2000. The foregut contained a mean food biomass of 0.9% body weight at this time. Schools of hybrids were frequently observed feeding along the shoreline at these times.

Daily consumption of the hybrids was computed as 44.0% of body weight at 23 C and 30.4% at 15 C. Food consumption estimates during six consecutive four hour intervals revealed that 37.5% of daily consumption occurred between 0400 and 0800 (Table 4). This interval represented the period of greatest consumption by the hybrid. The hybrid consumed the least vegetation between 2000 and 2400 when only 4.0% of daily consumption took place.

Survival of the hybrids over the 148 day study period was 59.1 and 32.2% in Ponds 1 and 2, respectively. Hybrids surviving to the end of the period averaged 542 g and 368 mm in Pond 1 and 591 g and 372 mm in Pond 2. This represents 3.3 and 3.6 g/day weight increases and an increase in length of 1.5 mm/day. Based on this information the final stock density was 107 kg/ha in Pond 1 and 117 kg/ha in Pond 2. Instantaneous rates of growth were 2.36 and 2.44 in Ponds 1 and 2, respectively.

No visible control of aquatic vegetation was achieved by the hybrids in either pond. By comparing the potential consumption of the hybrids with the actual biomass of vegetation present during each sampling interval (Figure 8) it is easily demonstrated why control was not obtained. Of the 5083 and 4612 kg of vegetation present in the

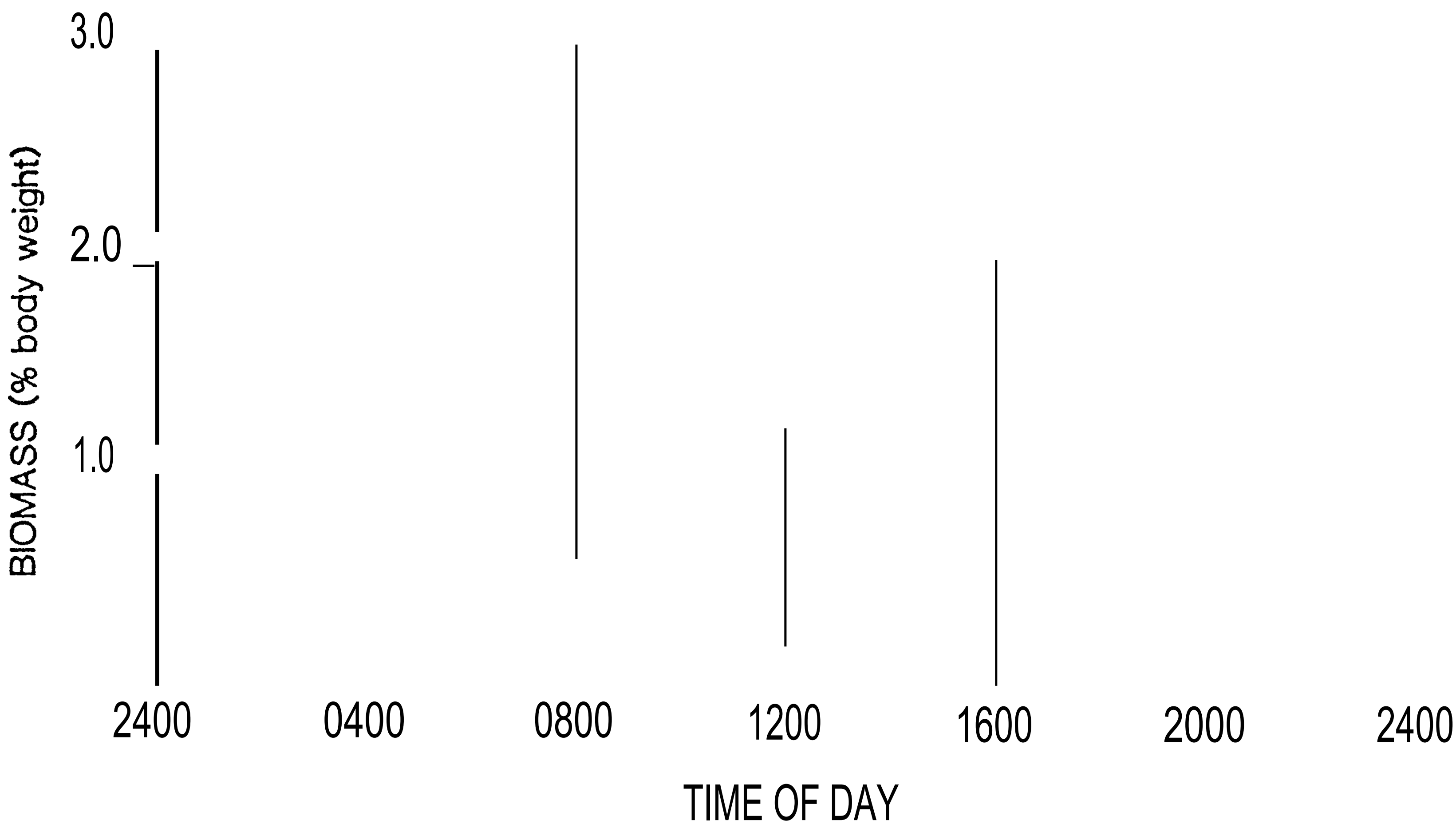

Figure 7. Mean biomass of food in the foregut of hybrids (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) at six consecutive four hour intervals in Pond 2.

Table 4. Consumption estimates of hybrids (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) during six consecutive four hour intervals at 23 C and 15 C

Interval	Consumption (% body weight)	
	23 C	15 C
2400 - 0400	5.5	3.8
0400 - 0800	16.5	11.4
0800 - 1200	6.4	4.4
1200 - 1600	5.5	3.8
1600 - 2000	8.3	5.7
2000 - 2400	1.8	1.3
Total Daily Consumption	44.0	30.4

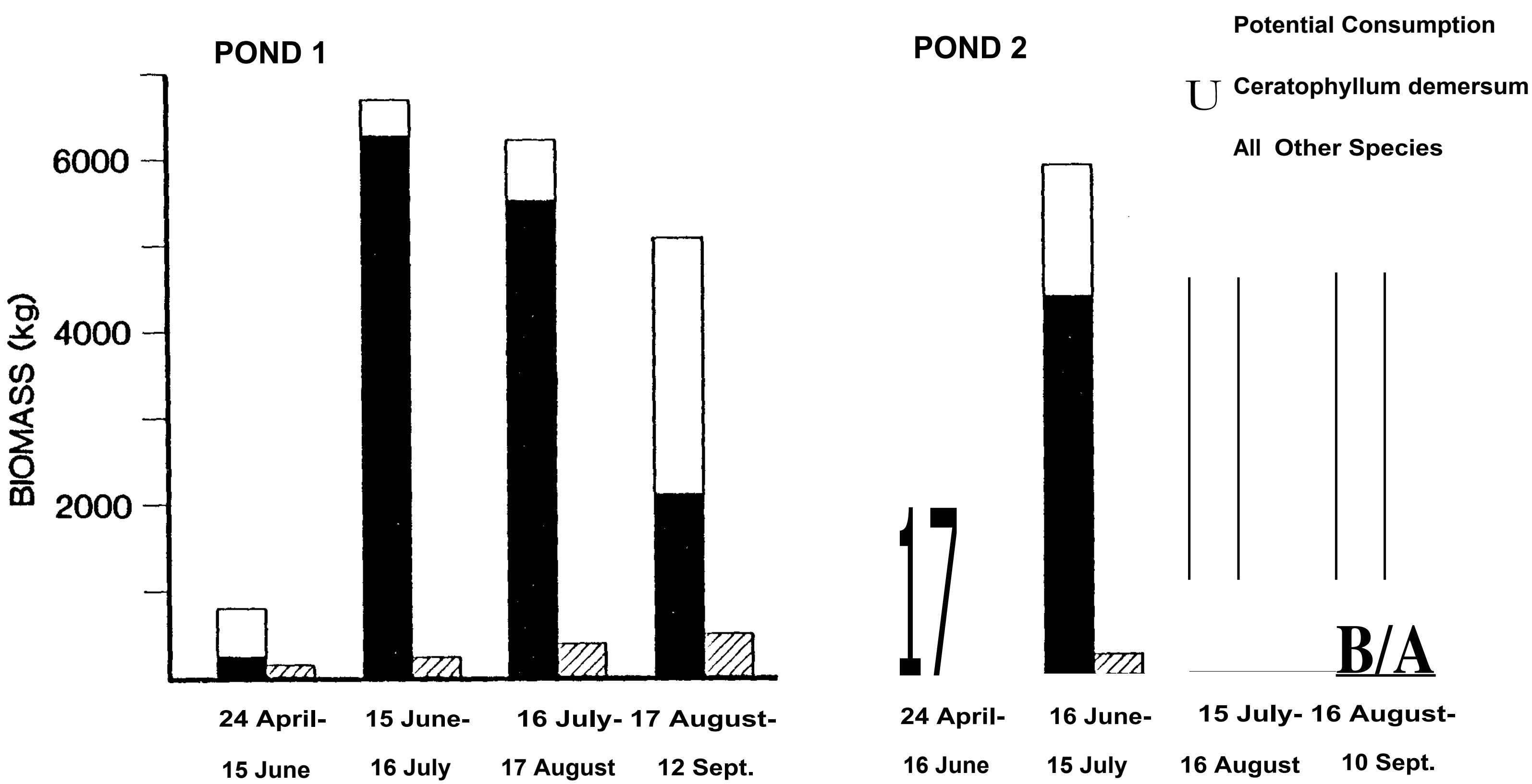

Figure 8. Biomass of vegetation within the stockwater ponds based on exclosed samples compared with the potential monthly consumption of hybrids (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) present in the ponds.

ponds at the end of the study only 9.7 and 10.5% could potentially have been controlled by the fish.

Water Quality

Water quality data for the ponds appears in Appendix Table 5 and 6. Due to ice cover on 21 February 1982 water samples were collected just beneath the ice and at the bottom.

Pond 1 was alkaline (pH 7.8-9.3, alkalinity 50-320 mg/i CaCO3) and moderately hard (100-190 mg/1 CaCO3). Pond 2 was slightly alkaline (pH 7.6-8.2, alkalinity 40-180 mg/1 $CaCO_3$) and very hard (750-1200 mg/l CaCO3). Dissolved oxygen levels of 5.0 and 3.0 mg/liter were recorded at the surface of Ponds 1 and 2, respectively, at approximately 0900 on 16-17 August 1982.

DISCUSSION

Hybrids exhibited a distinct pattern of plant selection. Under control conditions *Chara* sp., *Najas guadalupensis* and, to a lesser extent, *Potamogeton pectinatus* were consumed whereas *Ceratophyllum demersum* and *Myriophyllum spicatum* were not. No significant differences in species biomass between exposed and exclosed samples were detected in the stockwater ponds. However, N. *guadalupensis* was less abundant in the exposed area at both depth intervals indicating it may have been a preferred species. *Ceratophyllum demersum* was more abundant in the exposed samples at both depth intervals suggesting it may not have been used by the hybrid. Hestand and Chapman (1980), Cassani (1981), and Cassani and Caton (1983) reported similar results. Cassani (1981) also reported that C. *demersum* was preferred by young-of-the-year hybrids. However, C. *demersum* was one of the last plant species consumed by yearling hybrids when more preferred plant species were present (Cassani and Caton 1983). Yearling hybrids appeared to have plant preferences similar to juvenile white amur which selectively consumed *Chara, Najas,* and *Potamogeton* (Avault 1965; Stevenson 1965; Fowler and Robson 1978; Mitzner 1978). Kilambi and Zdinak (1980) reported that juvenile hybrids and white amur preferred *Potamogeton pusillus* over *Myriophyllum* and *Ceratophyllum.*

The interaction between depth and the effect of the hybrid on *Potamogeton pectinatus* may indicate a preference by the hybrid to feed in shallow areas. This relationship, although not significant, was also present for Chara sp., P. nodosus, R. longirostris and Potamogeton spp. A tendency of the hybrid to feed in shallow areas was observed by Osborne (1982). Nixon and Miller (1978) found that white amur preferred shallow areas in a Florida reservoir.

The spotty, non—uniform, growth of individual plant species in the stockwater ponds resulted in variability among vegetation samples. Due to this variation it was difficult to detect significant differences between treatments. In addition, shading may have masked differences by inhibiting plant growth within the exclosures. The effect of shading is believed to have been minor and was probably restricted to deeper areas in the ponds. Shading probably had a greater impact in Pond 2 where filamentous algae was observed on the exclosures.

Many of the plant species, which grew in the ponds, were preferred by hybrids according to the results of my study and those of other investigators. In September the hybrids had reached 500 g, a size at which they may have begun utilizing Ceratophyllum demersum. Edwards (1974) reported that white amur averaging approximately 500 g consumed greater amounts of C. demersum than white amur of approximately 200 g. The amount and composition of vegetation within the ponds probably provided optimum feeding conditions for the hybrid. However, due to the large amount of vegetation, oxygen levels might have become a problem during extended periods of cloud cover or at night when plant respiration was occurring. Shireman et al. (1977) reported that when oxygen content fell below 4.0 mg/l, white amur fingerlings consumed 45% less duckweed (Lemna sp.). Since oxygen levels of 3.0 and 5.0 mg/1 were recorded in the ponds at 0900 during the study period it is conceivable that levels below 4.0 mg/1 were present in the early morning hours. If consumption was diminished by 45% during the period of maximum feeding, vegetation control may have been affected.

Feeding activity of the hybrid was primarily diurnal with the greatest consumption occurring in the morning and evening. Nixon and Miller (1978) found that white amur were most active in a Florida reservoir during daylight hours. Stroganov (1963) reported that white amur fed most actively during morning and evening. The silver carp, _Hypophthalmichthys molitrix,_ a congener of the paternal parent of the hybrid, consumed the greatest amount of phytoplankton between 0400 and 0800 (0marov 1969). Minimum feeding took place between 2000 and 2400. Both maximum and minimum silver carp feeding periods matched those of hybrids in the present study.

Opuszynski (1972) reported that white amur began feeding on vegetation at approximately 12 C, although intensive feeding did not occur until 20 C. Stroganov (1963) stated that temperatures above 16 C caused intensive feeding by the white amur. At temperatures of 22-33 C consumption of the white amur reached a maximum (Opuszynski 1972). Since estimates of consumption in the present study were based on feeding activity at 15 C, the value of 44.0% of body weight at 23 C is probably a minimum. At 27 C, under laboratory conditions, Kilambi and Zdinak (1980) reported a maximum daily consumption rate of 74.9% body weight for yearling hybrids. Cassani and Caton (1983) found that between 25.7-31.0 C yearling hybrids had daily food consumption rates of 45% body weight of _Najas guadalupensis_ and 97% of _Chara._ White amur have been reported by numerous investigators to consume greater than

100% of their body weight daily under optimum conditions (e.g. Cross 1969; Edwards 1974; Vietmeyer 1976). Caldwell (1980) found that white amur (430 g) consumed 169% of body weight at an average temperature of 22.5 C; at an average temperature of 12.3 C white amur (600 g) consumed 52% of body weight. White amur consumption rates of 110-120% of body weight at 22-33 C and 50% of body weight at 20 C were reported by Opuszynski (1972). My results indicated that consumption rates of the hybrid were approximately one-third those of the white amur. This corresponded with rates found by Osborne (1982) in a Florida experimental pond. However, Shireman et al. (in press-b) reported that under laboratory conditions young-of-the-year hybrids consumed an average of 72% that of young-of-the-year white amur.

Throughout most of the present study, water temperature in the ponds was near the reported optimum for maximum consumption by white amur. However, during rotenone application on 18-19 September 1982 the temperature in both ponds was 15 C at 1100. Below this level white amur have been reported to feed at a minimum. Low temperatures occurred only toward the end of our study and therefore were probably not a factor limiting vegetation control.

Growth rates of hybrids in the stockwater ponds were greater than those of similarly sized hybrids held in Florida hatchery ponds, whose growth ranged from 0.72-0.98 mm/day (Hestand and Chapman 1980). Kilambi and Zdinak (1980) reported a maximum growth rate of 0.2 g/day for yearling hybrids under laboratory conditions which was also considerably less than growth rates attained in our study. Comparable growth rates of 2.4 and 3.5 g/day were reported by Freeze and Henderson for yearling hybrids under natural conditions. Lembi et al. (1978) reported that yearling white amur held in hatchery ponds grew at a rate of 9.8 g/day. In fertilized ponds the weight gain of yearling white amur was 11.2 and 7.2 g/day (Buck et al. 1978). A growth rate of 10.0 g/day was attained by white amur (90 g) during the first year after stocking in a Florida lake (Shireman et al. 1980). In this study the growth rate of yearling hybrids was roughly one-third that of similarly sized white amur. White amur regularly attain 1 kg in their first year under optimum conditions (Vietmeyer 1976). Hora and Pillay (1962) stated that white amur grow to between 225 and 650 g in one year. The hybrids appeared to require nearly two growing seasons to reach the size white amur reach after one season.

Shireman et al. (in press-a) reported that hybrids did not switch to a complete vegetation diet until they exceeded 200 mm. Hybrids in my study were stocked at 150 mm which may have allowed the plants to reach a point at which their growth rate exceeded the capacity of the hybrids to control them.

Survival rates in the present study were comparable to those of similarly sized hybrids stocked in a Florida lake where survival ranged from 30.0-57.0% (Hestand and Chapman 1980). Freeze and Henderson reported survival rates of 65.6 and 74.0% for hybrids held in 0.4 hectare hatchery ponds in Arkansas. A survival rate of 84.0% for white amur held in experimental ponds for 11 months was reported by Edwards (1974). Stott and Orr (1970) reported a survival rate of 94.6% for white amur stocked in a 0.49 hectare hatchery pond. The much lower survival rate of hybrids in Pond 2 is not understood. The landowner stated that most of the mortality in Pond 2 occurred approximately three weeks after stocking and coincided with a period of heavy rainfall. No piscivorous birds or mammals were observed near the ponds at any time.

It is obvious that the stocking rate used in this study was insufficient to achieve adequate control in the study ponds during the first season. Control of aquatic vegetation in the fist year, however, is not recommended since overgrazing the plant community could occur in subsequent years. Bailey (1975) recommended stocking 25 0.22 kg white amur per hectare (a stocking rate of approximately one-third that used in this study) to achieve suitable vegetation control in three years. Results of the present study indicated that approximately two to three times as many hybrids must be stocked to achieve similar control. However, the hybrid should not be regarded as impractical based solely upon data obtained with juvenile fish. Further study is needed on older hybrids before a decision can be made regarding the effectiveness of the hybrid and before exact stocking rates can be recommended.

LITERATURE CITED

Avault, J.W. 1965. Preliminary studies with grass carp for aquatic weed control. The Progressive Fish-Culturist 27:207-209.

Bailey, W.M. 1975. Operational experiences with the white amur in weed control programs. Pages 75-78 in Proceedings of the symposium on water quality management through biological control. University of Florida, Report No. ENV-07-75-1. Gainesville, Florida, USA.

Beck, M.L., C.J. Biggers, and H.K. Dupree. 1980. Karyological analysis <u>Ctenopharyngodon idella, Aristichthys nobilis</u> and their F_1 hybrids. Transactions of the American Fisheries Society 109:433-438.

Brett, J.R., and D.A. Higgs. 1970. Effect of temperature on the rate of gastric digestion in fingerling sockeye salmon, <u>Oncorhynchus nerka.</u> Canadian Journal of Fisheries and Aquatic Sciences 27:1767-1779.

Buck, D.H., R.J. Baur, and C.R. Rose. 1978. Utilization of swine manure in a polyculture of Asian and North American fishes. Transactions of the American Fisheries Society 107:216-222.

Caldwell, B.A. 1980. Ability of grass carp to control aquatic macrophytes in fish culture ponds in Colorado. Master thesis. Colorado State University, Fort Collins, Colorado, USA.

Cassani, J.R. 1981. Feeding behavior of underyearling hybrids of the grass carp, <u>Ctenopharyngodon idella</u> and the bighead, <u>Hypophthalmichthys nobilis</u> on selected species of aquatic plants. Journal of Fish Biology 18:127-133.

Cassani, J.R., and W.E. Caton. 1983. Feeding behavior of yearling and older hybrid grass carp. Journal of Fish Biology 22:35-41.

Colle, D.E., J.V. Shireman, and R.W. Rottman. 1978. Food selection by grass carp fingerlings in a vegetated pond. Transactions of the American Fisheries Society 107:149-152.

Conner, J.V., R.P. Gallagher, and M.F. Charty. 1980. Larval evidence for natural reproduction of the grass carp (*Ctenopharyngodon idella*) in the lower Mississippi River. Pages 1-19 in L.A. Fuiman, editor. Proceedings of the fourth annual larval fish conference. U.S. Fish and Wildlife Service, FWS/OBS-80-43. Washington, District of Columbia, USA.

Cross, D.G. 1969. Aquatic weed control using grass carp. Journal of Fish Biology 1:27-30.

Edwards, D.J. 1971. Effects of temperature on rate of passage of food through the alimentary canal of the *Pleuronectes plantessa* L. Journal of Fish Biology 3:433-439.

Edwards, D.J. 1974. Weed preference and growth of young grass carp in New Zealand. New Zealand Journal of Marine and Freshwater Research 8:341-350.

Edwards, D.J., and E. Moore. 1975. Control of water weeds by grass carp in a drainage ditch in New Zealand. New Zealand Journal of Marine and Freshwater Research 9:283-292.

Elliot, J.M. 1972. Rates of gastric evacuation in brown trout, *Salmo trutta* L. Freshwater Biology 2:1-18.

Elliot, J.M., and L. Persson. 1978. The estimation of daily rates of food consumption for fish. Journal of Animal Ecology 47:977-991.

Fowler, M.C., and T.O. Robson. 1978. The effects of the food preferences and stocking rates of grass carp (*Ctenopharyngodon idella* Val.) on mixed plant communities. Aquatic Botany 5:261-272.

Freeze, M., and S. Henderson. Unpublished manuscript.

Grove, D.J., and C. Crawford. 1980. Correlation between digestive rate and feeding frequency in the stomachless teleost, *Blennius pholis* L. Journal of Fish Biology 16:235-247.

Hestand, R.S. III, and P.G. Chapman. 1980. Annual progress report for hybrid grass carp. Florida Game and Freshwater Commission. Tallahassee, Florida, USA.

Hickling, C.F. 1966. On the feeding process in the white amur, *Ctenopharyngodon idella.* Journal of Zoology 148:408-419.

Hora, S.L., and T.V.R. Pillay. 1962. Handbook on fish culture in the Indo-Pacific region. F.A.O., Rome, Italy.

Kilambi, R.V., and A. Zdinak. 1980. Comparison of hybrid carp and grass carp with respect to food preference, food consumption and growth. National Marine Fisheries Service, P.L. 88-309, Project No. 2-361-R. Washington, District of Columbia, USA.

Kilambi, R.V., and A. Zdinak. 1981. Comparison of early developmental stages and adults of grass carp, *Ctenopharyngodon idella,* and hybrid carp (female grass carp x male bighead *Aristichthys nobilis).* Journal of Fish Biology 19:457-465.

Kitchell, J.F., and J.T. Windell. 1968. Rate of gastric digestion in pumkinseed sunfish, *Lepomis gibbosus.* Transactions of the American Fisheries Society 97:489-492.

Lembi, C.A., B.G. Ritenour, E.M. Iverson, and E.C. Forss. 1978. The effects of vegetation removal by grass carp on water chemistry and phytoplankton in Indiana ponds. Transactions of the American Fisheries Society 107:161-171.

Mitzner, L. 1978. Evaluation of biological control of nuisance aquatic vegetation by grass carp. Transactions of the American Fisheries Society 107:135-145.

Nixon, D.E., and R.L. Miller. 1978. Movements of grass carp, Ctenopharyngodon idella, in an open reservoir system as determined by underwater telemetry. Transactions of American Fisheries Society 107:146-148.

Omarov, M.O. 1969. The daily food consumption of silver carp Hypopthalmichthys molitrix (Val.). Journal of Ichthyology 10:425-426.

Opuszynski, K. 1972. Use of phytophagous fish to control aquatic plants. Aquaculture 1:61-74.

Osborne, J.A. 1982. The potential of the hybrid grass carp as a weed control agent. Journal of Freshwater Ecology 1:353-360

Pflieger, W.L. 1978. Distribution and status of the grass carp (Ctenopharyngodon idella) in Missouri streams. Transactions of the American Fisheries Society 107:113-118.

Shireman, J.V., D.E. Colle, and M.J. Maceina. 1980. Grass carp growth rates in Lake Wales, Florida. Aquaculture 19:379-382.

Shireman, J.V., D.E. Colle, and R.W. Rottman. 1977. Intensive culture of grass carp, Ctenopharyngodon idella, in circular tanks. Journal of Fish Biology 11:267-272.

Shireman, J.V., and C.R. Smith. 1981. Biological synopsis of grass carp (Ctenoparyngodon idella). U.S. Fish and Wildlife Service, Final Report Contract No. 14-16-0009-78-912. Washington, District of Columbia, USA.

Shireman, J.V., F.J. Aldridge, and R.W. Rottman. In press-a. Growth and food habits of hybrid carp from aerated and non-aerated ponds. Journal of Fish Biology.

Shireman, J.V., R.W. Rottman, and F.J. Aldridge. In press-b. Consumption and growth of hybrid grass carp fed four vegetation diets and trout chow in circular tanks. Journal of Fish Biology.

Springer, R.R. 1979. Soil survey of Tripp County, South Dakota. National Cooperative Soil Survey. U.S. Soil Conservation Service. Washington, District of Columbia, USA.

Stanley, J.G., W.W. Miley, II, and D.L. Sutton. 1978. Reproductive requirements and likelihood for naturalization of escaped grass carp in the United States. Transaction of the American Fisheries Society 107:119-128.

Stevenson, J.H. 1965. Observations on grass carp in Arkansas. The Progressive Fish-Culturist 27:203-206.

Stott, B., and L. Orr. 1970. Estimating the amount of aquatic weed consumed by grass carp. The Progressive Fish-Culturist 32:51-54.

Stroganov, N.S. 1963. The food selectivity of the amur fishes. Pages 181-191 in Problems of the fisheries exploitation of plant-eating fishes in the water bodies of the USSR. Ashkhabad, Akad, Nauk Turkmen. SSSR. (Cited in Hickling 1966 and Shireman and Smith 1981).

Sutton, D.L., J.G. Stanley, and W.W. Miley, II. 1981. Grass carp hybridization and observations of a grass carp x bighead hybrid. Journal of Aquatic Plant Management 19:37-39.

Terrell, J.W., and T.T. Terrell. 1975. Macrophyte control and food habits of the grass carp in Georgia ponds. Verh. International. Verein. Limnol. 19:2515-2520.

Tyler, A.V. 1970. Rates of gastric emptying in young cod. Canadian Journal of Fisheries and Aquatic Sciences 27:1177-1189.

Vietmeyer, N.D. 1976. 1 Grass Carp. Pages 15-21 in N.D. Vietmeyer. Making aquatic weeds useful: some perspectives for developing countries. National Academy of Sciences, Washington, District of Columbia, USA.

Welch, P.S. 1952. Limnology. Second edition. McGraw-Hill Book Company, New York, New York, USA.

Woynarovich, E. 1968. New Systems and new fishes for culture in Europe. Pages 162-181 in Pillay, T.V.R., editor. Proceedings of the world symposium on warm-water pond fish culture. FAO Fisheries Reports 5:(44). Rome, Italy.

APPENDIX

Appendix Table 1. Analysis of variance of percent plant consumption by hybrids (*Hypophthalmichthys nobilis* X *Ctenopharyngodon idella*) due to different species evaluated in trial 1 and trial 2.

Source of variation	Degrees of freedom	Mean square	F value
Trial 1			
Plant species	4	8992.4	18.6*
Error	10	482.4	
Trial 2			
Plant species	4	9639.3	276.8*
Error	10	36.0	

*Significant at .0001 level of probability.

Appendix Table 2. Biomass (g/0.25 m^2) of plant species collected at sampling stations in two Tripp County stockwater ponds during the summer of 1982.

[illegible]	[illegible]	[illegible]	Najas guadalupensis		Potamogeton pectinatus	Potamogeton [illegible]	Potamogeton [illegible]	Ranunculus [illegible]	Ceratophyllum [illegible]
Section 1									
0 - 0.9 m									
Exclosed	1	15 June	0.0	0.0	0.0	9.4	0.0	0.0	3.5
Exposed	1	15 June	21.1	0.0	0.0	0.5	0.0	0.0	1.3
0.9 - 1.8 m									
Exclosed	1	15 June	0.0	0.0	0.0	3.0	0.0	0.0	117.9
Exposed	1	15 June	0.0	0.0	0.0	23.1	0.0	0.0	2.4
Section 2									
0 - 0.9 m									
Exclosed	1	15 June	0.0	0.0	0.0	3.1	0.0	0.0	0.5
Exposed	1	15 June	0.0	0.0	0.0	4.7	2.3	0.0	0.0
0.9 - 1.8 m									
Exclosed	1	15 June	0.0	0.0	0.0	8.1	0.0	0.0	2.3
Exposed	1	15 June	0.0	0.0	0.0	15.5	0.0	0.0	14.4
Section 3									
0 - 0.9 m									
Exclosed	1	15 June	0.0	0.0	0.0	0.9	0.0	0.0	0.5
Exposed	1	15 June	0.0	0.0	0.0	9.3	0.0	0.0	0.5
0.9 - 1.8 m									
Exclosed	1	15 June	0.0	0.0	52.5	0.0	0.0	0.0	26.6
Exposed	1	15 June	0.0	0.0	16.1	0.0	0.0	0.0	6.6

Appendix Table 2. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Potamogeton pectinatus	Potamogeton spp.	Potamogeton [illegible]	[illegible] longirostris	Ceratophyllum [illegible]
Section 1									
0 - 0.9 m									
Exclosed	1	16 July	275.6	253.4		47.8	39.1	0.0	0.0
Exposed	1	16 July	154.1	10.2	0.0	0.0	17.8	3.6	33.8
0.9 - 1.8 m									
Exclosed	1	116	146.2	34.5	0.1	48.3	11.2	4.8	2 8
Exposed	1	6 July	50.1	97.1	0.0	207.4	62.3	26.1	11.1
Section 2									
0 - 0.9 m									
Exclosed	1	16 July	100.1	3.4	28.9	0.0	7.7	0.0	0.0
Exposed	1	16 July	17.8	8.4	54.1	93.2	32.7	1.1	0.0
0.9 - 1.8 m									
Exclosed	1	16 July	2.6	0.0		76.8	0.0	2.6	105.4
Exposed	1	16 July	1.0	0.0	201.6	8.4	0.0	0.0	57.8
Section 3									
0 - 0.9 m									
Exclosed	1	16 July	42.0	12.1		470.5	21.3	4.4	4.7
Exposed	1	16 July	5.3	5.9	5.4	162.9	221.1	123.0	3.2
0.9 - 1.8 m									
Exclosed	1	16 July	91.7	0.0	41.0	5.1	0.0	0.0	7.3
Exposed	1	16 July	103.7	5.0	49.1	32.1	1.8	4.6	1.1

Appendix Table 2. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Potamogeton pectinatus	Potamogeton spp.	Potamogeton nodosus	Ranunculus longirostris	Ceratophyllum demersum
Section 1										
0 - 0.9 m										
Exclosed	1	17 August	200.8	61.2		0.0	1.1	33.5	0.0	0.0
Exposed	1	17 August	0.0	0.0		0.0	0.0	23.6	0.0	2.9
0.9 - 1.8 m										
Exclosed	1	17 August	157.7	58.5		0.0	21.4	68.9	6.1	2.9
Exposed	1	17 August	14.1	81.7		18.6	5.7	22.6	29.9	0.5
Section 2										
0 - 0.9 m										
Exclosed	1	17 August	332.3	0.0		0.3	0.0	10.6	0.0	0.0
Exposed	1	17 August	551.2	3.3		0.0	11.9	5.3	0.0	4.7
0.9 - 1.8 m										
Exclosed	1	17 August	0.0	0.0		9.5	77.6	0.0	0.0	196.2
Exposed	1	17 August	0.0	0.0		3.6	27.9	0.0	0.0	216.4
Section 3										
0 - 0.9 m										
Exclosed	1	17 August	104.9	0.0		21.9	3.6	133.0	0.0	0.0
Exposed	1	17 August	383.5	2.3		0.0	0.5	24.8	1.3	8.9
0.9 - 1.8 m										
Exclosed	1	17 August	260.4	0.0		0.0	0.5	0.0	0.0	0.0
Exposed	1	17 August	97.7	8.9		87.6	22.2	80.9	106.5	57.9

Appendix Table 2. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Potamogeton pectinatus	Potamogeton	Potamogeton	Ranunculus	Ceratophyllum
Section 1									
0 - 0.9 m									
Exclosed	1	12 September	0.6	106.4	0.0	0.0	59.5	0.0	0.0
Exposed	1	12 September	0.2	119.8	0.0	0.0	62.5	1.0	5.5
0.9 - 1.8 m									
Exclosed	1	12 September	1.7	12.0	0.0	0.0	0.6	0.2	0.0
Exposed	1	12 September	1.2	0.7	15.6	0.0	4.9	0.1	23.8
Section 2									
0 - 0.9 m									
Exclosed	1	12 September	168.7	0.0	0.0	0.7	88.0	0.0	89.7
Exposed	1	12 September	2.7	0.0	0.0	3.4	22.2	7.8	56.2
0.9 - 1.8 m									
Exclosed	1	12 September	0.0	0.0	0.0	0.0	0.0	0.0	747.0
Exposed	1	12 September	0.0	0.0	0.0	0.0	8.0	0.0	89.8
Section 3									
0 - 0.9 m									
Exclosed	1	12 September	0.0	0.0	0.0	0.0	149.4	0.0	0.0
Exposed	1	12 September	5.8	0.0	0.0	0.0	41.9	8.5	25.1
0.9 - 1.8 m									
Exclosed	1	12 September	0.0	0.0	0.0	0.0	12.9	0.0	1.4
Exposed	1	12 September	1.0	34.7	0.0	0.0	57.4	16.8	36.3

Appendix Table 2. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Potamogeton pectinatus	Potamogeton [illegible]	Potamogeton [illegible]	Ranunculus longirostris	Ceratophyllum
Section 1									
0-0.9m									
Exclosed	2	16 June	0.0	0.0	15.3	0.0	0.0	13.4	164.5
Exposed	2	16 June	0.0	0.0	1.5	0.0	3.1	3.1	36.1
0.9 - 1.8 m									
Exclosed	2	16 June	0.0	0.0	0.0	0.0	0.0	0.0	170.4
Exposed	2	16 June	0.0	249.8	0.0	0.0	0.0	191.2	26.0
Section 2									
0-0.9m									
Exclosed	2	16 June	0.0	0.0	0.0	12.3	0.0	3.8	233.7
Exposed	2	16 June	0.0	0.0	0.0	0.0	0.0	17.2	11.6
0.9 - 1.8 m									
Exclosed	2	16 June	0.0	902.6	0.0	0.0	0.0	3.1	0.0
Exposed	2	16 June	0.0	734.7	34.0	0.0	0.0	17.9	0.0
Section 3									
0 - 0.9 m									
Exclosed	2	16 June	0.0	0.0	0.0	34.5	0.0	96.6	69.5
Exposed	2	16 June	0.0	0.0	0.5	4.6	0.0	9.6	144.9
0.9 - 1.8m									
Exclosed	2	16 June	0.0	176.8	0.9	0.0	0.0	0.0	33.3
Exposed	2	16 June	0.0	795.8	0.0	0.0	0.0	0.0	10.7

Appendix Table 2. (Continued)

ampling tation	[illegible]	[illegible]	[illegible]	Chara sp.	Potamogeton pectinatus	Potamogeton spp.	Potamogeton nodosus	Ranunculus longirostris	Ceratophyllum demersum
Section 1									
0 - 0.9 m									
Exclosed	2	15 July	0.0	3.1	52.1	19.3	0.0	6.0	171.3
Exposed	2	15 July	0.0	2.6	5.0	1.4	0.0	0.0	27.7
0.9 - 1.8 m									
Exclosed	2	15 July	0.0	63.0	0.0	0.0	0.0	0.0	80.9
Exposed	2	15 July	0.0	51.5	0.0	0.0	0.0	73.6	0.1
Section 2									
0 - 0.9 m									
Exclosed	2	15 July	0.0	0.0	0.3	0.0	0.0	176.3	80.1
Exposed	2	15 July	0.0	0.0	1.6	0.0	0.0	210.0	105.0
0.9 - 1.8 m									
Exclosed	2	15 July	0.0	456.2	1.1	0.0	0.0	20.1	1.4
Exposed	2	I5 July	0.0	30.4	103.3	70.8	0.0	72.5	81.3
Section 3									
0 - 0.9 m									
Exclosed	2	15 July	0.0	0.0	0.0	153.4	0.0	4.3	58.4
Exposed	2	15 July	0.0	0.0	20.8	269.0	0.0	0.0	284.3
0.9 - m									
Exclosed	2	15 July	0.0	308.5	2.4	0.0	0.0	0.0	43.7
Exposed	2	15 July	0.0	243.8	5.8	0.0	0.0	0.0	66.4

Appendix Table 2. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Potamogeton pectinatus	Potamogeton spp.	Potamogeton nodosus	Ranunculus longirostris	Ceratophyllum demersum
Section 1									
0 - 0.9 m									
Exclosed	2	16 August	0.0	0.0	37.1	0.0	0.0	5.1	400.1
Exposed	2	16 August	0.0	0.0	0.0	0.0	0.0	0.0	338.8
0.9 - 1.8 m									
Exclosed	2	16 August	0.0	0.0	0.0	0.0	0.0	0.0	188.8
Exposed	2	16 August	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Section 2									
0 - 0.9 m									
Exclosed	2	16 August	0.0	0.0	3.5	12.9	0.0	170.1	261.2
Exposed	2	16 August	0.0	0.4	43.4	0.0	3.6	0.0	298.1
0.9 - 1.8 m									
Exclosed	2	16 August	27.7	0.0	0.0	0.0	0.0	0.0	0.0
Exposed	2	16 August	0.0	0.0	97.5	0.0	0.0	0.0	451.0
Section 3									
0 - 0.9 m									
Exclosed	2	16 August	0.0	0.0	7.4	0.0	0.0	33.0	41.7
Exposed	2	16 August	0.0	0.0	26.8	0.0	0.0	26.5	361.4
0.9 - 1.8 m									
Exclosed	2	16 August	0.0	0.0	1.0	0.0	0.0	0.4	126.3
Exposed	2	16 August	0.0	18.1	32.0	0.0	0.0	3.4	84.2

Appendix Table 2. (Continued)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Potamogeton pectinatus	Potamogeton [illegible]	Potamogeton [illegible]	[illegible] longirostris	Ceratophyllum [illegible]
Section 1									
0 - 0.9 m									
Exclosed	2	10 September	0.0	0.0	0.0	0.0	0.0	1.9	467.1
Exposed	2	10 September	0.0	0.0	2.0	0.0	0.0	1.7	443.9
0.9 - 1.8 m									
Exclosed	2	10 September	0.0	0.0	3.6	0.0	0.4	0.0	50.4
Exposed	2	10 September	0.0	0.0	0.0	0.0	0.0	0.0	86.4
Section 2									
0 - 0.9 m									
Exclosed	2	10 September	0.0	0.0	152.6	0.1	3.6	46.4	309.6
Exposed	2	10 September	0.0	0.0	0.0	0.0	0.0	0.0	741.1
0.9 - 1.8 m									
Exclosed	2	10 September	0.0	0.0	0.0	0.0	0.0	3.6	15.7
Exposed	2	10 September	0.0	0.0	0.0	0.0	0.0	0.0	764.3
Section 3									
0 - 0.9 m									
Exclosed	2	10 September	0.0	0.0	58.4	0.2	0.0	0.0	177.8
Exposed	2	10 September	0.0	0.0	31.0	0.0	0.0	2.0	621.9
0.9 - 1.8 m									
Exclosed	2	10 September	0.0	0.0	1.9	0.0	0.0	0.0	37.0
Exposed	2	10 September	0.0	0.0	37.1	0.0	0.0	0.0	83.1

Appendix Table 3. Analysis of variance of the mean biomass of *Potamogeton pectinatus* collected in the exposed and exclosed area within depth intervals.

Source of variation	Degrees of freedom	Mean square	F value
Depth	1	60350.5	0.63
Type	1	161622.1	1.68
Depth * Type	1	636841.3	6.61**
Error	64	96329.2	

Significant at the .05 level of probability.

Appendix Table 4. Analysis of variance of the linear models relating time to the natural logarithm of food biomass present in the foregut at 23 C and 15 C.

Source of variation	Degrees of freedom	Mean square	F value
15 C			
Model	1	118.4	24.2
Error	19	4.9	
23 C			
Model	1	88.7	19.3[**]
Error	13	4.6	

Significant at .0001 level of probability.

[**] Significant at .001 level of probability.

Appendix Table 5. Water quality data collected from Pond 1 between 20 August 1981 and 17 August 1982.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20 August 1981											
Surface	-	24.0	8.0	9.3	27.0	1.0	1750	150	170	0.36	0.11
Mid-depth	1.1	23.0	5.0	9.2	18.0	0.9	1700	100	170	0.36	0.11
Bottom	2.2	20.0	1.0	8.8	20.0	0.7	1450	100	260	0.90	0.14
14 November 1981											
Surface	-	10.0	12.0	8.5	32.0	1.0	1350	160	320	0.35	0.10
Mid-depth	0.8	9.5	12.0	8.5	28.0	1.0	1340	190	300	0.34	0.08
Bottom	1.6	9.5	13.0	8.7	30.0	1.0	1320	140	280	0.35	0.08
21 February 1982											
Surface	Ice	-	-	-	-	-	-	-	-	-	-
Mid-depth	0.8	2.5	10.0	7.8	105.0	0.2	330	120	50	0.18	2.10
Bottom	1.6	.2.0	10.0	7.8	150.0	0.2	330	100	60	0.19	1.70
24 April 1982											
Surface	-	13.0	11.0	8.4	41.0	0.5	820	150	160	0.04	0.06
Mid-depth	1.4	11.5	10.0	8.4	50.0	0.5	780	145	160	0.04	0.07
Bottom	2.8	11.5	10.0	8.4	40.0	0.5	760	145	160	0.04	0.06
17 August 1982											
Surface	-	26.0	5.0	8.5	35.0	0.5	1100	100	25	0.02	0.06
Mid-depth	1.5	25.0	3.0	8.4	70.0	0.5	1100	100	120	0.01	0.06
Bottom	3.0	23.5	0.0	7.8	125.0	0.5	1100	140	200	0.06	0.08

Appendix Table 6. Water quality data collected from Pond 2 between 19 August 1981 and 18 August 1982.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19 August 1981											
Surface	-	25.0	7.0	7.6	2.0	1.5	2920	800	120	0.06	0.04
Mid-depth	0.75	25.0	6.0	7.6	2.0	1.5	2920	840	150	0.06	0.06
Bottom	1.50	25.0	6.0	7.6	2.0	1.5	2920	850	150	0.05	0.04
14 November 1981											
Surface	-	9.0	13.0	7.9	7.5	1.2	1740	1160	100	0.01	0.02
Mid-depth	0.75	9.5	13.0	7.8	11.0	1.2	1740	1140	40	0.00	0.00
Bottom	1.50	9.5	14.0	8.2	2.0	1.2	1750	1150	110	0.00	0.02
21 February 1982											
Surface	Ice	-	-	-	-	-	-	-	-	-	-
Mid-depth	0.75	3.0	11.0	7.8	55.0	0.6	2100	750	100	0.08	0.44
Bottom	1.50	4.0	11.0	7.8	12.0	1.8	2100	1200	180	0.05	0.05
24 April 1982											
Surface	-	17.5	9.0	7.8	10.0	1.2	2200	1130	120	0.01	0.00
Mid-depth	0.75	16.0	10.0	7.7	10.0	1.2	2100	1080	125	0.01	0.01
Bottom	1.50	15.5	14.0	7.7	10.0	1.2	2050	1080	120	0.00	0.00
18 August 1982											
Surface	-	26.0	3.0	7.8	12.0	1.2	2500	990	80	0.00	0.04
Mid-depth	0.75	25.5	3.0	7.8	10.0	1.2	2500	1000	80	0.01	0.04
Bottom	1.50	25.5	3.0	7.8	10.0	1.2	2500	1000	60	0.00	0.03